Page Proof Instructions and Queries

Journal Title: Waste Management & Research

Article Number: 733539

Thank you for choosing to publish with us. This is your final opportunity to ensure your article will be accurate at publication. Please review your proof carefully and respond to the queries using the circled tools in the image below, which are available **by clicking "Comment"** from the right-side menu in Adobe Reader DC.*

Please use *only* the tools circled in the image, as edits via other tools/methods can be lost during file conversion. For comments, questions, or formatting requests, please use T. Please do *not* use comment bubbles/sticky notes.

*If you do not see these tools, please ensure you have opened this file with **Adobe Reader DC**, available for free at get.adobe.com/reader or by going to Help > Check for Updates within other versions of Reader. For more detailed instructions, please see us.sagepub.com/ReaderXProofs.

No.	Query
	Please confirm that all author information, including names, affiliations, sequence, and contact details, is correct.
	Please review the entire document for typographical errors, mathematical errors, and any other necessary corrections; check headings, tables, and figures.
	Please ensure that you have obtained and enclosed all necessary permissions for the reproduction of art works (e.g. illustrations, photographs, charts, maps, other visual material, etc.) not owned by yourself. Please refer to your publishing agreement for further information.
	Please note that this proof represents your final opportunity to review your article prior to publication, so please do send all of your changes now.
	Please confirm that the Funding and Conflict of Interest statements are accurate.
1	ASTM (1992). When was this most recently accessed?
2	Castellón Town Council (2010). Please provide more details for this reference. Is it available online?
3	European Commission (2016). When was this most recently accessed?
4	Gallardo (2000). Not cited in text. Either delete from list or cite in text
5	IVE (2012). When was this most recently accessed?
6	IVE (2012). Not cited in text. Either delete from list or cite in text
7	MAGRAMA (2015). Please confirm whether the supplied URL is correct
8	MAGRAMA (2015). Not cited in text. Either delete from list or cite in text
9	Zhen-shan et al. (2011). Not cited in text. Either delete from list or cite in text

Original Article

WM&R

Waste Management & Research
1–9
© The Author(s) 2017
Reprints and permissions:
sagepub.co.uk/journalsPermissions.nav
DOI: 10.1177/0734242X17733539
journals.sagepub.com/home/wmr
SAGE

Analysis of the waste selective collection at drop-off systems: Case study including the income level and the seasonal variation

Gallardo A, Carlos M, Colomer F J and Edo-Alcón N

Abstract

There are several factors which have an influence in the selective collection of the municipal waste. To define a selective collection system, the waste generation pattern should be firstly determined and these factors should be analyzed in depth. This paper tries to analyze the economic income level and the seasonal variation on the collection and the purity of light-packaging waste to determine actions to improve the waste management plan of a town. In the first stage of the work, waste samples of the light-packaging containers were collected in two zones of the town with different economic characteristics in different seasons during one year. In the second stage, the samples were characterized to analyze the composition and purity of the waste. They were firstly separated into four fractions: metals; plastic; beverage cartons; and misplaced materials. The misplaced fraction was in its turn separated into cardboard, rubber and leather, inert waste, organic matter, paper, hazardous waste, clothes and shoes, glass and others. The plastic fraction was separated into five types of plastics and the metal fraction into three. In the third stage, the data have been analyzed and conclusions have been extracted. The main result is that the quality of the light-packaging fraction collected in these zones during both seasons were similar. This methodology can be extrapolated to towns with similar characteristics. It will be useful when implementing a system to collect the waste selectively and to develop actions to achieve a good participation in the selective collection of the waste.

Keywords

Income, waste, selective collection, characterization, purity

Received 25th May 2017, accepted 5th September 2017 by Associate Editor Mario Grosso.

Introduction

In recent years, the world economic growth has originated an excessive increase in the generation of municipal solid waste (MSW). The population growth, especially in urban areas, the progressive products obsolescence and the generalized use of packaging are some of the factors that make waste management improvement more necessary than ever. Therefore, citizens as well as politicians are becoming aware of this waste generation growth and as a result their efforts to improve waste management have increased (Castagna et al., 2013; Sakai et al., 2011). Identifying and characterizing the factors that determine why a local authority opts for a particular way of managing its waste collection service is an important issue, warranting research interest in the field of MSW management (Plata-Díaz et al., 2014). In some cases, legislation encourages local authorities to take measures to carry out the options that deliver the best overall environmental outcome. In this sense, European strategies in waste management are related to plans to reduce waste generation, source separation, valorization, and waste final disposal. The European Waste Directive, 19 November 2008 (European Commission, 2016) establishes a waste hierarchy which states a priority order in waste prevention and management legislation and policy. The first step of this hierarchy focuses on prevention, followed by re-use, recycling, recovery, and the final waste disposal. In order to achieve satisfactory results in recovering materials from the MSW, selective collection systems have been implemented. Depending on the country, the fractions to be collected can vary and the selective collection systems are organized in different ways. A careful evaluation of the planning and the implementation of the selective collection programs, contributes to decision-making, to the adoption of corrective actions, to the confirmation of program performance, and to strengthening the ties with the target population (Bringhenti et al., 2011). The level of recovery of the different waste fractions depends on several factors. Waste management planning requires reliable

Department of Mechanical Engineering and Construction, Jaume I University, Spain

Corresponding author:
Mar Carlos, Department of Mechanical Engineering and Construction, Jaume I University, Avenida de VicentSosBaynat s/n, Castelló de la Plana, 12071, Spain.
Email: mcarlos@uji.es

data concerning waste generation, influencing factors on waste generation, and forecasts of waste quantities based on facts. But first of all, the waste generation pattern of the town should be determined. There are several factors, such as physical, geographical, socio-cultural, economic, and political factors, which have an influence in the composition and generation of MSW. To manage MSW adequately it is essential to know these variables as precisely as possible in a specific geographic area (Gallardo et al., 2014). Purcell and Magette (2009) hypothesized socio-economic variables, housing types, and the sizes and main activities of commercial establishments as the key determinants contributing to the spatial variability of biodegradable municipal waste generation. Suthar and Singh (2015) estimated the quantity and quality of household waste in terms of socio-economic groups and family size in Dehradun city, India. Lebersorger and Beigl (2011) identified and quantified differences of the MSW collection of several towns based on data from waste management and on socio-economic indicators. The resulting regression model included municipal tax revenue per capita, household size and the percentage of buildings with solid fuel heating systems. Owusu et al. (2013) examined the willingness of urban households in Ghana to accept economic incentives to participate in solid waste source separation; low-income households were less inclined to accept cash incentives than middle-income or high-income households indicating that factors other than purely cost for waste management are important for households to participate in source-separation of waste. Kesser et al. (2012) took into account spatial dependency in determination of the significant socio-economic and climatic factors that may be of importance for the MSW generation rates in different provinces of Turkey. Thanh et al. (2010) evaluated the quantity and composition of household solid waste to identify opportunities for waste recycling in Can Tho city, the capital city of the Mekong Delta region in southern Vietnam. These authors also analyzed the relations between some socio-economic factors and household solid waste generation rates by physical categories and subcategories. Gómez et al. (2009) analyzed and compared the findings of the study of the characterization and the generation of solid waste from households at three different socio-economic levels in a Mexican city over three periods (April and August, 2006 and January, 2007). Akinci et al. (2012) investigated the major components and characteristics of the domestic solid wastes as a function of economic conditions for a study area, in order to define the recycling resources and biomass recovery options, as well as to discuss the possible waste management methods for these regions. These authors also considered seasonal variations as the purity of recyclable and residual MSW is, among other factors, strongly influenced by the seasonal variation in MSW composition. However, a relatively marginal amount of published data on seasonal MSW composition does not provide sufficient information on this phenomenon. Denafas et al. (2014) provided results from municipal waste composition research campaigns in four cities of Eastern European countries. Mateu-Sbert et al. (2013) estimated the impact of the tourist population on MSW, both total and separately collected, for the period 1998–2010, for the Mediterranean island of Menorca (Spain) using regressions models.

The success of the waste recovery is also related to the stakeholder's implication. Therefore, some authors have studied the citizen's behavior in the selective collection process. Swami et al. (2011) analyzed the frameworks of waste management behavior by examining personality, individual differences, and socio-demographic antecedents of self-reported waste recycling, reuse, and reduction behaviors in Britain. Lee and Paik (2011) examined the impacts of several factors on recycling and waste management behaviors, attitudes for recycling and waste management, and the respondents' demographic variables. Gallardo et al. (2013) studied the influence of the income level of the families on the quantity of paper/cardboard and light-packaging collected separately at drop-off points. Results showed that in the zones with a medium–high income level the collection rates (in liters per inhabitant and year) were higher in both cases than in the zones with a medium–low income level. In an econometric analysis, Jenkins et al. (2003) showed that the average income in households had a significant impact on the collaboration in the separation of paper.

The aim of this work is to analyze the influence of the income level and seasonal variations on the collection and the purity of light-packaging wastes collected in a drop-off point, in order to establish the adequate preventive measures. To achieve this aim two neighborhoods of the same town with a clear difference in their income level have been identified. In each zone, the selective collections of the light-packaging fraction have been monitored during the months of April and October of the same year. It consisted in determining the purity of the light-packaging containers and the possible variation between both periods. Each drop-off point has a container for the glass fraction and another one for the light-packaging fraction. The research work has only been focused on the container of the light-packaging fraction because the purity in the other containers was very high (between 97% and 99%) (Gallardo et al., 2010). In this sense, no significant differences were expected in both zones.

Finally, the methodology proposed in this study and the conclusions extracted can be extrapolated to other towns with similar characteristics. The results will be useful when implementing a system of selective collection of MSW, and especially when it is applied in towns with sectors of different income level.

Materials and methods

The methodology followed in this research work has several steps which are shown in Figure 1. This methodology is also explained step by step.

Analysis of the situation

The selected area is Castellón, a middle-sized town located on the east coast of Spain, in the Comunidad Valenciana. Castellón

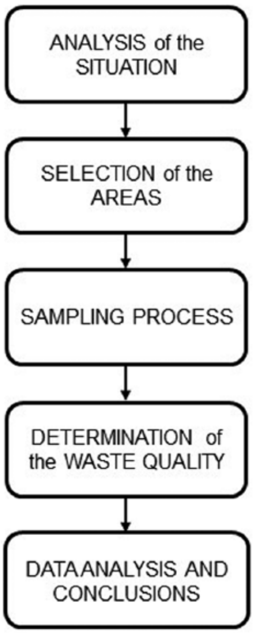

Figure 1. Steps of the methodological work.

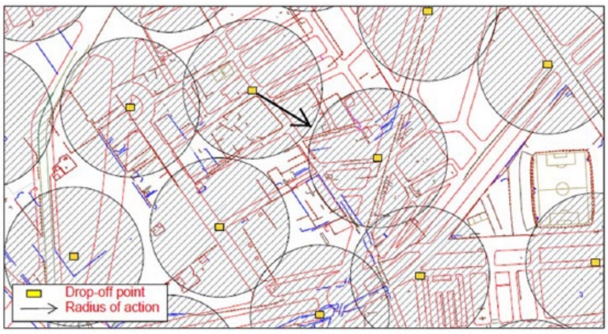

Figure 2. Example of drop-off points with radius of action of 100 m.

has a population of 156,221 inhabitants. The town of Castellón is not a touristic town. For this reason, there is not an increase in the number of inhabitants with other customs or life style during the year. The town is about 6 km from the beach. In summer, around 30% of the people leave the town and go to the nearby coastal or mountain villages and the rest of the people remain at their homes.

In this town, waste is basically separated into four fractions: paper/cardboard; glass; light-packaging (plastics, metals and beverage carton); and mixed waste. The mixed waste is picked up from kerbside containers of 1,100 L, with a separation between them of 50 m to 60 m, whereas the paper/cardboard, glass and light-packaging are collected in 3,200 L containers from drop-off points that have a radius of action of 100 m to 150 m (Gallardo et al., 2010). The radius of action (Figure 2) is defined as the greatest distance from the disposal point in a straight line. In every drop-off point, there are usually three containers: one for the paper/cardboard; one for light-packaging; and one for glass. Nowadays, Castellón has 238 containers to collect paper/cardboard, 245 containers to collect light-packaging, and 220 containers to collect glass. People who live in this town usually drop their waste in the container next to their homes. Citizens drop the garbage in the evening and they walk to the nearest container as the radius of action of the containers is 100 m.

Other types of specific waste are also collected separately. The electrical and electronic waste equipment (WEEE) are collected together with the bulky waste (furniture and small amount of debris) and the hazardous household waste (pots of paint, medical X-ray or radiography sheets, etc.) in a local waste facility for recycling, located at 3 km from the town. Large WEEE (such as fridges, washing machines, televisions, etc.) and other bulky waste (such as old furniture) can also be collected door to door by the collection services after consulting. The batteries, fluorescent tubes and medicines are collected in containers located at approved establishments (mainly the establishments where they were sold). Finally, the clothes waste and the used cooking oil are collected at special drop-off points.

Selection of the study areas

Taking into account the citizens' income, a town can be divided into subareas. To analyze MSW generation, several authors (Bandara et al., 2007) use four income levels: high income; medium–high income; medium income; and low income. Other authors, such as Gómez et al. (2009), compare waste generation in households at three socio-economic levels (lowest level: 1–2 times the minimum salary; medium level: 2–5 minimum salary; and highest level: more than 5 minimum salary). According to Emery et al. (2003), socio-economic levels in the form of different types of dwellings have an influence on the final quantities and composition of waste disposal, which are in some cases quite substantial. Castellón cannot be divided into subareas from the citizens' income point of view because there is no available information. Hence, to divide it into areas of different purchasing power another strategy is to know the amount of waste that was carried out. The town was divided depending on the urban characteristics of the zone as other authors such as Emery et al. (2003) proposed. According to the data provided by the Town Council, Castellón is divided into 178 land value zones that have been evaluated taking into account their location, accessibility, housing development, urban services quality, and the real estate market dynamics. As a result, each area of the town has its own land economic value (€ m^{-2}). Therefore, to carry on this research work the town was divided into two areas depending on the land economic value. The first zone was considered a medium–high income zone (HZ) with land values between 500 €·$m^{-2}$and 900 €·m^{-2} and the second zone, was the low–medium income zone (LZ), with land values between 150 €·$m^{-2}$and 500 €·m^{-2}.

The distance from the citizen to the container is another factor that has an influence on the selective collection systems (Gallardo et al., 2010). Consequently, to avoid its influence on the results, two subzones with drop-off points with the same radius of action were selected. To make a complete work, it was interesting to

Table 1. Data about the sampling process.

	April		October	
	First subzone (HSZ)	Second subzone (LSZ)	HSZ	LSZ
Weight sample 1 (kg)	18	19	29	19
Weight sample 2 (kg)	22	25	32	27

study two areas that met two conditions: they should be large enough (to study an elevated number of drop-off points); and they should have a radius as small as possible (to have a greater amount of waste separated). The radius of action that meets both conditions was 100 m (see Figure 2).

According to the Register of inhabitants of the Castellón Town Council (2010), the number of inhabitants in the first subzone (HSZ) selected was 10,935 inhabitants which are covered by 51 drop-off points. The number of inhabitants in the second subzone (LSZ) was 27,227 inhabitants, with 32 drop-off points. In the HSZ the buildings have fewer numbers of floors than the buildings in the LSZ, consequently there are fewer inhabitants. In each drop-off point, there is a container for light-packaging.

Sampling process and determination of the purity of the waste

The second part of the research work consisted of determining the purity of the waste collected selectively in both zones. The purity is defined by the percentage of appropriate materials that appear in the container. The bigger is the percentage of these type of materials, the bigger will be the purity.

The composition study was then focused on the light-packaging fraction, which is more likely to contain a greater percentage of misplaced materials due to the heterogeneity of the materials collected and to the lack of information of the population about the type of waste that should be dropped in this container (Gallardo et al., 2010). Therefore, two sampling campaigns were carried out during two seasons of the same year, the first one in spring and the second one in autumn with the aim of analyzing the possible differences between them. In this geographical zone, the seasons of spring and summer are quite similar, and the seasons of autumn and winter are also quite similar. For this reason, the months selected to carry out the sampling process were April (for the spring–summer season) and October (to represent the autumn–winter season). Equations (1) and (2) (Bartlett et al., 2001) were used to determine the amount of sample needed. Equation (1) is as follows

$$n_0 = \left(\frac{tS}{e\overline{X}} \right)^2 \quad (1)$$

where:

n_0 is the sample size

t is the confidence level that is determined by α. The confidence level used is 95% ($\alpha = 0.05$), and therefore $t = 1.96$.

$\overline{X}$ is the average

S is the standard deviation.

e is the tolerable level of error of the average. It is an estimated value and here it has been considered as 10%.

If the sample size n_0 is greater than 5% of the population size, the size sample corrected equation (2) (Bartlett et al., 2001) should be used

$$n = \frac{n_0}{1 + \frac{n_0}{N}} \quad (2)$$

where N is the population size and n is the new sample size. These formulae rely on the assumption of normal distribution. In this paper a normal distribution has been assumed, taking into account the example of the Standard D 5231-92 (ASTM, 1992).

In the first place, the minimum number of points to be sampled to estimate the composition of the light-packaging stream is calculated. The previous data of the average value and the standard deviation of the light-packaging fraction in the container in Castellón have been extracted from the data published by Ecoembes (2012; www.ecoembes.es). Using equation (1) and the following values: t = 1.96, e = 0.05, S = 5.99, and $\overline{X}$ = 87.57 (percentage of light-packaging in the container) the results show that n_o = 7. In the HSZ where N = 51 containers, n_o is greater than 5% of N, consequently equation (2) must be used. The final result is n = 6. Therefore, samples must be taken at least in 6 containers. For the LSZ, the result is n = 6 (N = 32). Subsequently, the composition was determined. Two samples were taken in one week in each zone in April. In the HSZ, the samples were taken on Tuesday morning and Thursday morning, taking 18 kg and 22 kg. The samples were homogeneously taken from 6 containers. In the LSZ, the process was similar; the samples were taken the same days in the afternoon. The samples weights were 19 kg and 25 kg. In October, the same procedure was carried out. In the HSZ 29 kg and 32 kg were taken and in the LSZ 19 kg and 27 kg were sampled. The samples were taken, as in the previous campaign, homogeneously from 6 containers. All these data are summarized in Table 1.

All these samples were characterized at the laboratory. In the first place, the samples were characterized in metals, plastic, beverage carton and misplaced materials, as shown in Table 2 and Table 3. After this first characterization, the misplaced material was also characterized. This fraction was separated into several materials such as, cardboard, rubber and leather, inert waste, organic matter, paper, hazardous waste, clothes and shoes, toys, glass and others, as shown in Table 4 and Table 5. Finally, a third characterization was done to analyze the composition of the plastic and the metal fractions of the light-packaging containers as Figures 3 to 6 show.

Table 2. Waste composition (average and standard deviation) in light-packaging containers in first subzone.

(%)	April		October	
	Average	Standard deviation	Average	Standard deviation
Metals	14.0	0.6	15.4	2.9
Plastic	54.0	3.0	56.7	6.1
Beverage carton	15.3	4.7	11.9	1.6
Misplaced materials	16.7	1.1	16.0	7.4

Table 3. Waste composition (average and standard deviation) in light-packaging containers in second subzone.

(%)	April		October	
	Average	Standard deviation	Average	Standard deviation
Metals	15.2	5.4	19.0	3.7
Plastic	54.2	2.3	52.4	3.7
Beverage carton	13.5	1.2	17	2.1
Misplaced materials	17.1	6.5	11.6	2.1

Table 4. Composition of the misplaced fraction in first subzone.

(%)	April		October	
	Average	Standard deviation	Average	Standard deviation
Cardboard	2.4	0.8	1.2	1.7
Rubber and leather	0.3	0.4	0.6	0.6
Inert waste	0.0	0.0	0.0	0.0
Organic matter	3.4	2.5	3.0	2.5
Paper	3.4	0.5	2.7	0.7
Hazardous waste	2.3	0.9	3.2	2.4
Clothes and shoes	0.1	0.1	0.7	0.9
Toys	0.00	0.00	0.6	0.7
Glass	2	0.7	2.7	3.8
Others	2.8	1.9	1.3	1.6

Table 5. Composition of the misplaced fraction in second subzone.

(%)	April		October	
	Average	Standard deviation	Average	Standard deviation
Cardboard	2.6	0.4	2.8	0.1
Rubber and leather	0.1	0.05	0.1	0.2
Inert waste	0.5	0.6	0.0	0.0
Organic matter	5.1	6	0.3	0.3
Paper	2.8	2.2	2.4	2.63
Hazardous waste	1.8	1.6	1.4	1.2
Clothes and shoes	0.4	0.1	3.1	1.5
Toys	0.0	0.0	0.0	0.0
Glass	2.1	0.3	1.2	1.7
Others	1.7	0.6	0.3	0.4

The waste separation work was carried out by the researchers, who have a great experience in this field as they usually characterize waste at the laboratory for waste companies. The waste is separated manually with a previous visual inspection except for ferrous waste that is separated with magnets. The different types of plastics (polypropylene, polystyrene, high-density polyethylene, and low-density polyethylene) can be separated as all the plastic packaging in Europe are categorized by a number from 1 to 7 according to the ASTM International Resin Identification Coding System. The film fraction has been considered as

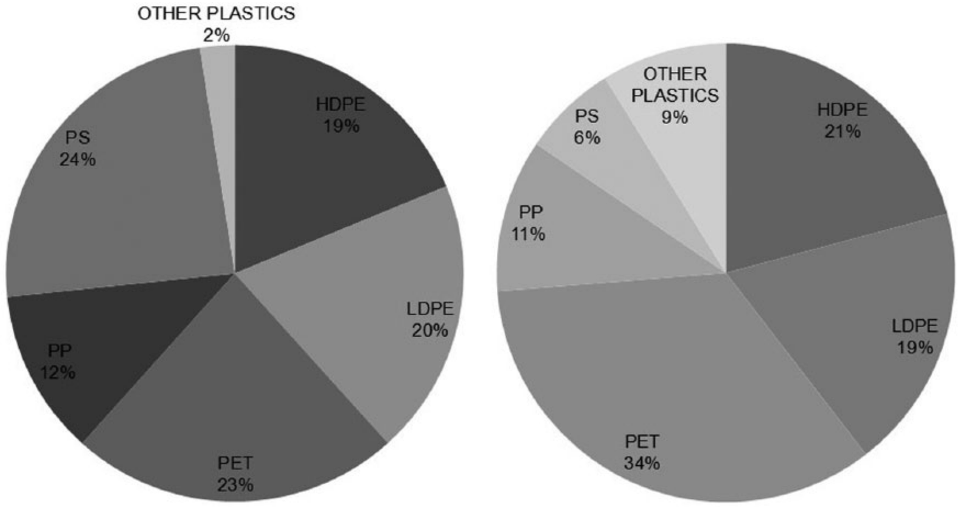

Figure 3. Composition of the plastic fraction in light-packaging containers in first subzone, April (left) and October (right).

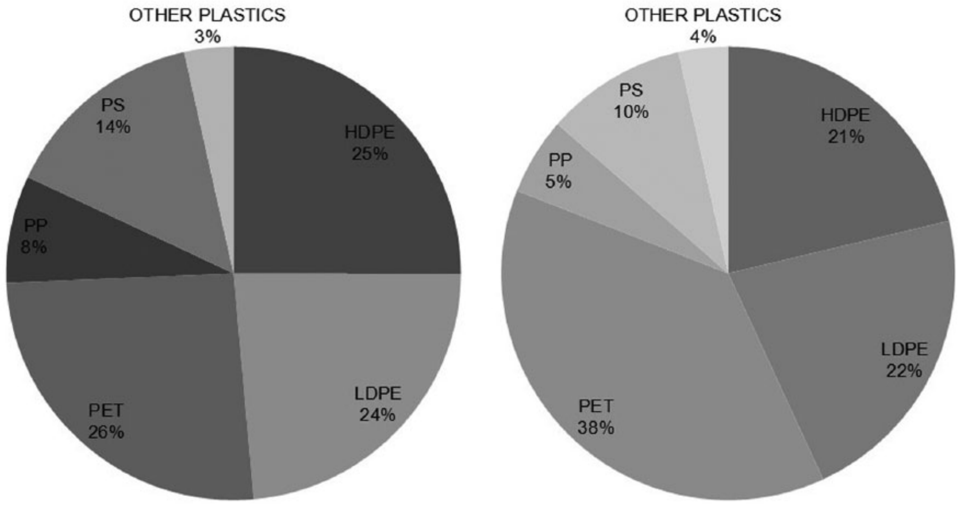

Figure 4. Composition of the plastic fraction in light-packaging containers in second subzone, April (left) and October (right).

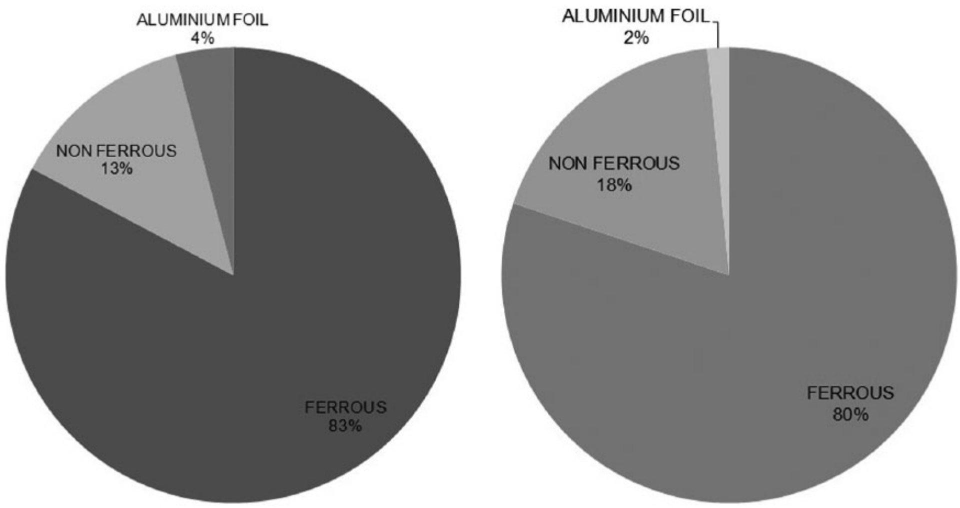

Figure 5. Composition of the metal fraction in light-packaging containers in first subzone, April (left) and October (right).

low-density polyethylene. Nevertheless, this fraction can be formed by a mixture of other type of plastics such as polyvinyl chloride (PVC) stretch-wrap film. In order to detect if there is any difference in the composition between both periods (April and

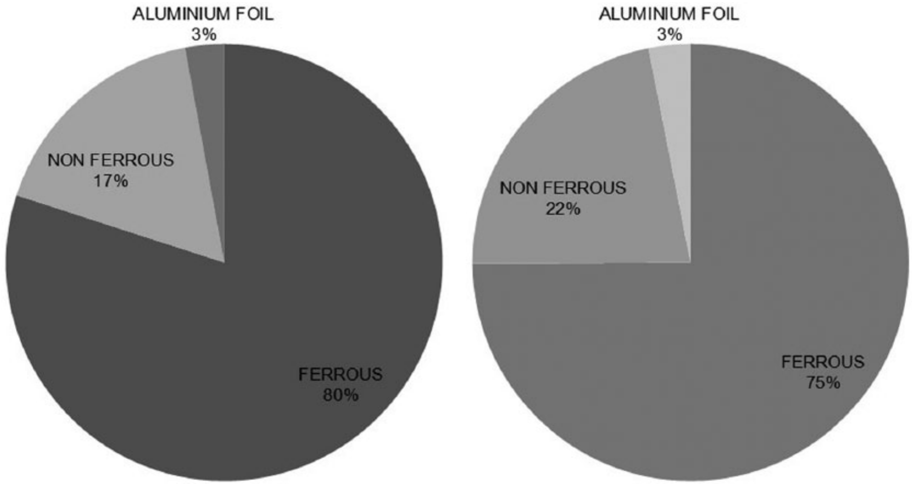

Figure 6. Composition of the metal fraction in light-packaging containers in second subzone, April (left) and October (right).

October) in each zone, statistical analysis of the data was performed. All the statistical analyses were calculated using the R free open source software. In this case, due to the number of data per sample being very small (only two characterizations in each period and in each zone), a non-parametric test was used. Therefore, to detect if there are any differences in both periods (April and October) and in each zone (HSZ and LSZ), the Wilcoxon rank-sum test was used for each component of the waste and zone, with 95% of confidence level ($\alpha = 0.05$), as in the work of Gallardo et al. (2016).

Results and discussion

After characterizing the samples taken in the light-packaging containers, results about the waste composition in these containers were extracted. Table 2 shows the results (average and standard deviation) of the waste composition in the HSZ (medium–high income level) in both periods, April and October, whereas Table 3 shows the results for LSZ (low–medium income level).

Attending to the results in Table 2, the plastic is the biggest fraction in containers in HSZ during April with 54% ($S = 3$), followed by misplaced materials, beverage carton, and metal fractions. In October, plastic is still the biggest fraction with a value of 56.6% ($S = 6.1$) followed by the misplaced fraction. However, the metal fraction is the third and beverage carton is the smallest fraction. Regarding the misplaced fraction, it can be said that there is a similar percentage between both periods of time, 16.7% ($S = 1.1$) in April and 16.0% ($S = 7.4$) in October.

Results in Table 3 show the composition in containers in LSZ. It must be highlighted that the misplaced fraction decreases slightly in the second period of the year, from 17.1% ($S = 6.6$) in April to 11.6% ($S = 2.1$) in October.

As commented before, to determine if there are any differences in the composition in the containers in both zones, the Wilcoxon rank-sum test was used with 95% of confidence level ($\alpha = 0.05$). Results in Table 6 confirm that there are no differences in April and October between HSZ and LSZ (all the p-values > 0.05). Therefore, it should be noted that there are no differences in the percentage of misplaced materials between both zones and in the two studied periods.

To compare and determine if there are differences in the waste composition in April and October, the same test has been used for HSZ and LSZ. Results in Table 7 show that there are no differences in the waste composition in the containers in HSZ and LSZ in both periods. Consequently, it should be highlighted that there are no differences in the percentage of misplaced materials between April and October in both zones.

Finally, one of the main conclusions that can be extracted from the results is that the percentage of misplaced materials in the light-packaging container in both zones is similar. The same occurs with the two periods studied. The citizens who collaborated in the waste selective collection in HSZ and in LSZ have the same level of knowledge about the correct way to drop the waste in the street containers.

Furthermore, in this research work, it has been realized that there is a percentage of misplaced material in the containers. To explain the reasons for this fact, the misplaced material was analyzed in the two zones and in the two periods. Table 4 and Table 5 present the results of the absolute percentages of the materials of the misplaced fraction.

In all the cases, paper, cardboard and glass fractions are between 1.2% and 3.4%. This could be due to the paper/cardboard and glass containers being completely full. For this reason, citizens decided to place these types of waste in a wrong place, the light-packaging container. Another possible reason could be that citizens did not know how to place the waste correctly. Organic matter also appears in a great percentage (between 0.3% and 5.1%). This fraction was present in some packaging. Finally, taking into account the results presented in Table 7, it can be said that there are no differences between April and October (for each zone) or between zones.

In general, in both zones the annual purity in the light-packaging container is very high, 83.6% in the HSZ and 85.6% in the LSZ, if it is compared to the average value of the Spanish cities which is around 76% (Gallardo et al., 2010). This fact means that the citizens in both zones know which type of waste should be dropped in the light-packaging container, although this practice can be improved.

Table 6. Results of the Wilcoxon rank-sum test for each period.

	April		October	
	W	*p*-value	*W*	*p*-value
Metals	2.0	1.00	1.0	0.67
Plastic	2.0	1.00	3.0	0.67
Beverage carton	2.0	1.00	0.0	0.33
Misplaced materials	2.0	1.00	3.0	0.67
High-density polyethylene	0.0	0.33	2.0	1.00
Low-density polyethylene	1.0	0.67	2.0	1.00
Polyethylene terephthalate	1.0	0.67	1.0	0.67
Polypropylene	3.0	0.67	4.0	0.33
Polystyrene	4.0	0.33	0.0	0.33
Other plastics	2.0	1.00	4.0	0.33
Aluminum foil	3.0	0.67	0.0	0.33
Ferrous	2.0	1.00	0.0	0.33
Non-ferrous	0.0	0.33	2.0	1.00
Cardboard	2.0	1.00	0.0	0.33
Rubber and leather	3.0	0.67	3.0	0.67
Inert waste	1.0	0.62	–	–
Organic matter	2.0	1.00	4.0	0.33
Paper	2.0	1.00	2.0	1.00
Hazardous waste	2.0	1.00	3.0	0.67
Clothes and shoes	0.0	0.33	0.0	0.33
Toys	–	–	4.0	0.22
Glass	2.0	1.00	2.5	1.00
Others	3.0	0.67	2.5	1.00

Table 7. Results of the Wilcoxon rank-sum test for each zone.

	First subzone		Second subzone	
	W	*p*-value	*W*	*p*-value
Metals	2.0	1.00	1.0	0.67
Plastic	1.0	0.67	3.0	0.67
Beverage carton	3.0	0.67	0.0	0.33
Misplaced materials	2.0	1.00	3.0	0.67
High-density polyethylene	2.0	1.00	4.0	0.33
Low-density polyethylene	2.0	1.00	4.0	0.33
Polyethylene terephthalate	0.0	0.33	0.0	0.33
Polypropylene	2.0	1.00	3.0	0.67
Polystyrene	4.0	0.33	4.0	0.33
Other plastics	0.0	0.33	2.0	1.00
Aluminum foil	4.0	0.33	0.0	0.33
Ferrous	2.0	1.00	2.0	1.00
Non-ferrous	1.0	0.67	2.0	1.00
Cardboard	3.0	0.67	1.0	0.67
Rubber and leather	1.0	0.67	1.5	1.00
Inert waste	–	–	3.0	0.62
Organic matter	3.0	0.67	4.0	0.33
Paper	3.0	0.67	3.0	0.67
Hazardous waste	2.0	1.00	3.0	0.67
Clothes and shoes	1.0	0.67	0.0	0.33
Toys	0.0	0.22	–	–
Glass	2.0	1.00	2.0	1.00
Others	3.0	0.67	4.0	0.33

In all the cases, the plastic fraction represents the biggest percentage of recovery. This fraction has also been characterized to define the type of plastics that compose it. The following types of plastics were separated in the characterization: high-density polyethylene; low-density polyethylene; polyethylene terephthalate; polypropylene; polystyrene; and others (mixture of plastics). The results of these new characterizations are presented in Figures 3 and 4. A conclusion that can be extracted is that plastic packaging made only by one material is the most common. It could be due to two reasons, in the first place, this kind of plastic packaging is easily identified by the people and in the second place it is the most used. Strikingly, the manual sorting trials suggest that PVC is absent in the light-packaging containers. From this fact, it could be deduced that this type of plastic would not be present in the reject fraction generated. Consequently, it would be very useful to be turned into solid recovered fuel as it has a low content in chlorine (Gallardo et al., 2014).

To conclude, in order to detect if there are differences in the waste composition, the Wilcoxon rank-sum test was used for each of the periods (April and October) and zones (HSZ and LSZ) with a 95% confidence level ($\alpha = 0.05$). The contrast statistical data and their associated *p*- values are shown in Table 6 and Table 7. Attending to the results in Table 6 and Table 7, the associated *p*-values of each plastic fraction are greater than α. Consequently, it can be assumed that there are no differences in the composition of the different types of plastics between periods or zones.

Moreover, the metal fraction was also characterized. In this case, three types of materials were separated: ferrous materials; non-ferrous materials; and aluminum foil. Figures 5 and 6 show the results of the metals characterization. The predominant fraction is the ferrous fraction formed by the packaging of beverages and preserved food (tomato, prepared food, seafood, etc.) as in Spain the canning industry is very important and its products are highly consumed. As mentioned in the case of the plastic fraction, attending to the results in Table 6 and Table 7, it can be said that there are no differences between the percentages of the different types of metals in April and October or between the zones, since the associated *p*-values are greater than α.

Conclusions

Two factors that have an effect in the MSW selective collection are the citizens' income level and the seasonal variation. Therefore, it is important to take them into account to design a selective collection plan.

An experiment has been designed, and it has been implemented in two zones of Castellón de la Plana, covering 38,162 citizens, to determine how these factors affect the purity of the waste collected selectively. The purity of the waste collected has been analyzed during two periods (April and October).

Attending to the percentage of purity in the light-packaging containers, it was similar in both zones (it varies between 83.6% and 85.6%). There were no differences between seasons. This fact allows to ensure that people who participate in the selective collection in both zones have the same level of knowledge about how to do it. Moreover, in the case of the light-packaging, the percentage is even higher than the Spanish average that is 76%.

Regarding the waste composition, it was similar in both zones. Additionally, no differences have been found between both seasons. The first conclusion could be due to the fact that Castellón is not a touristic town, for this reason there is not an increase of population during the year with a different life style. Moreover, the zone has a Mediterranean climate characterized by mild winters and hot summers with slight variations of temperatures. From the income level point of view, no variations have been found in the waste composition. People discard the same type of light-packaging but these packages contain different kind of goods.

Finally, the methodology and the conclusions extracted from this study can be extrapolated to other towns with similar characteristics. The results will be useful when implementing a system of selective collection of MSW, and especially to develop actions for society in order to achieve participation of everybody in the waste collection system.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

Akinci G, Guven ED and Gok G (2012) Evaluation of waste management options and resource conservation potentials according to the waste characteristics and household income: A case study in Aegean Region, Turkey. *Resources, Conservation and Recycling* 58: 114–124.

ASTM ~~(1992)~~ Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste. D 532 1-92, September. Available at: http://dl.mozh.org/uploads/141642738205921.pdf (accessed). [AQ: 1]

Bandara NJ, Hettiaratchi JP, Wirasinghe SC, et al. (2007) Relation of waste generation and composition to socio-economic factors: A case study. *Environmental Monitoring Assessment* 135: 31–39.

Bartlett JE, Kotrlik JW and Higgins CC (2001) Organizational research: Determining appropriate sample size in survey researches. *Information Technology, Learning Performance Journal* 19: 43–50.

Bringhenti JR, Zandonade E and Günther WMR (2011) Selection and validation of indicators for programs selective collection evaluation with social inclusion. *Resources, Conservation and Recycling* 55: 876–884.

Castagna A, Casagranda M, Zeni A, et al. (2013) 3R'S from citizens point of view and their proposal from a case-study. *UPB Science Bulletin, Series D: Mechanical Engineering* 75: 253–264.

Castellón Town Council (2010) *Register of Inhabitants*. [AQ: 2]

Denafas G, Ruzgas T, Martuzevičius D, et al. (2014) Seasonal variation of municipal solid waste generation and composition in four East European cities. *Resources, Conservation and Recycling* 89: 22–30.

Ecoembes (2012) Available at: www.ecoembes.es (accessed 15 December 2012).

Emery AD, Griffiths AJ and Williams PK (2003) An in depth study of the effects of socio-economic conditions on household waste recycling practice. *Waste Management and Research* 21: 180–190.

European Commission (2016) Directive 2008/98/EC of the European Parliament and of the Council 19 November 2008 on waste and repealing certain Directives. Available at: http://ec.europa.eu/environment/waste/framework/ (accessed). [AQ: 3]

~~Gallardo A (2000) *Metodología para el diseño de redes de recogida selectiva de RSU utilizando sistemas de información geográfica. Creación de una base de datos aplicable a España* [Methodology for the design of selective collection of MSW using geographic information systems. Creation of a database applicable to Spain]. PhD Thesis. Universidad Politécnica de Valencia. [In Spanish.]~~ [AQ: 4]

Gallardo A, Bovea MD, Colomer F, et al. (2010) Comparison of different collection systems for sorted household waste in Spain. *Waste Management* 30: 2430–2439.

Gallardo A, Gómez A, Bovea MD, et al. (2013) Influencia del nivel de ingresos económicos en la recogida selectiva de residuos urbanos [Influence of the level of economic income on the selective collection of urban waste]. *Revista Internacional de Contaminación Ambiental* 29: 19–24. [In Spanish.]

Gallardo A, Carlos M, Peris M, et al. (2014a) Methodology to design a municipal solid waste generation and composition map: A case study. *Waste Management* 34: 1920–1931.

Gallardo A, Carlos M, Bovea MD, et al. (2014b) Analysis of refuse-derived fuel from the municipal solid waste reject fraction and its compliance with quality standards. *Journal of Cleaner Production* 83: 118–125.

Gallardo A, Edo-Alcón N, Carlos M, et al. (2016) The determination of waste generation and composition as an essential tool to improve the waste management plan of a university. *Waste Management* 53: 3–11.

Gómez G, Meneses M, Ballinas L, et al. (2009) Seasonal characterization of municipal solid waste (MSW) in the city of Chihuahua, Mexico. *Waste Management* 29: 2018–2024.

~~IVE (2012) Ficha municipal de Castellón de la Plana. Actualización 2012. Institut Valencià d'Estadística. [In Spanish.] Available at: http://www.lesuseres.es/files/archivos/201301/12122.pdf (accessed).~~ [AQ: 5] [AQ: 6]

Jenkins RR, Martínez S., Palmer K, et al. (2003) The determinants of household recycling: A material-specific analysis of recycling program features and unit pricing. *Journal of Environmental Economics and Management* 45: 294–318.

Keser S, Duzgun S and Aksoy A (2012) Application of spatial and non-spatial data analysis in determination of the factors that impact municipal solid waste generation rates in Turkey. *Waste Management* 32: 359–371.

Lebersorger S and Beigl P (2011) Municipal solid waste generation in municipalities: Quantifying impacts of household structure, commercial waste and domestic fuel. 2011. *Waste Management* 31: 1907–1915.

Lee S and Paik HS (2011) Korean household waste management and recycling behaviour. *Building and Environment* 46: 1159–1166.

~~MAGRAMA (2015) Ministerio de Agricultura, Pesca, Alimentación y Medio Ambiente de España. Available at: http://www.magrama.gob.es/es/calidad-y-evaluacion-ambiental/ (accessed 10 September 2015).~~ [AQ: 7] [AQ: 8]

Mateu-Sbert J, Ricci-Cabello I and Villalonga-Olives E (2013) The impact of tourism on municipal solid waste generation: The case of Menorca Island (Spain). *Waste Management* 33: 2589–2593.

Owusu V, Addjei-Addo E and Sundberg C (2013) Do economic incentives affect attitudes to solid waste source separation? Evidence from Ghana. *Resources, Conservation and Recycling* 78: 115–123.

Plata-Díaz AM, Zafra-Gómez JL, Pérez-López G, et al. (2014) Alternative management structures for municipal waste collection services: The influence of economic and political factors. *Waste Management* 34: 1967–1976.

Purcell M and Magette WL (2009) Prediction of household and commercial BMW generation according to socio-economic and other factors for the Dublin region. *Waste Management* 29: 1237–1250.

Sakai S, Yoshida H, Hirai Y, et al. (2011) International comparative study of 3R and waste management policy developments. *Journal of Material Cycles and Waste Management* 13: 86–102.

Suthar S and Singh P (2015) Household solid waste generation and composition in different family size and socio-economic groups: A case study. *Sustainable Cities and Society* 14: 56–63.

Swami V, Chamorro-Premuzic T, Snelgar R, et al. (2011) Personality, individual differences, and demographic antecedents of self-reported household waste management behaviours. *Journal of Environmental Psychology* 3: 21–26.

Thanh NP, Matsui Y and Fujiwara T (2010) Household solid waste generation and characteristic in a Mekong Delta city, Vietnam. *Journal of Environmental Management* 91: 2307–2321.

~~Zhen-shan Li, Hui-zhen Fu and Xiao-yan Qu (2011) Estimating municipal solid waste generation by different activities and various resident groups: A case study of Beijing. *Science of the Total Environment* 409: 4406–4414.~~ [AQ: 9]